Environmental Health Perspectives
Vol. 32, pp. 5-9, 1979

Role of Mathematics in Cancer Research: Attitudes and Training of Japanese Mathematicians

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An extensive survey of attitude towards scientific information of scientists in Japan was conducted in Japan. It was published in a technical report, and this survey is reviewed in this paper, with the hope that this will furnish findings important in working out the plan for promoting exploitation of mathematical talent in biomedical research. Findings are concordant with the impression of foreign visitors: (1) pure mathematicians tend to concentrate on mathematics only; (2) applied mathematics and statistics are heavily oriented toward industry; (3) mathematicians and pharmacologists are very different in their attitudes to scientific information. Based on the personal experience of the author, difficulties to be circumvented in utilizing aptitudes for mathematics and/or statistics in biomedical research are discussed.

Introduction

In 1976, an extensive survey was conducted by a group headed by Professor M. Kotani of Tokyo Science University concerning the attitude towards various aspects of scientific information of Japanese scientists (*1*). I was a member of the group, functioning as a statistician. Sampling was from the directory of senior staffs of universities and colleges with graduate teaching programs. The coverage of the survey, or the portion of directory in each institution included sciences, engineering, agriculture, and pharmacology but excluded medicine, dentistry, economics, law, education, and humanities. Two identical sets of questionnaires were sent to each of those sampled asking him to answer the one by himself and to select a younger staff member to answer the other. The number of responses was 1240, 42% of the total numbers of questionnaires mailed.

The analysis is now going on, and we are now convinced that the outcome of the survey is a fair representation of Japanese scientific community. We feel that this will also furnish findings important in working out the plan for promoting exploitation of mathematical talent in biomedical research, although medical schools are excluded from the coverage of the survey. This paper is a brief review of a few aspects of the findings.

Number of fields committed

At the very beginning of the questionnaires, the respondent is asked to indicate interest in at most three of 60 areas of scientific disciplines shown in Table 1. These 60 areas are not concordant with the division of sciences and technologies currently employed by the Japanese Ministry of Education; rather they reflect the interests of those scientists who worked out the questionnaires. The answers to this question are summarized in Table 1.

Table 1 strongly indicates the sharp difference between area 1 (pure mathematics) and area 2 (applied mathematics and mathematical statistics). The ratio I / (I + II + III) is 0.80 in category 1 and is the largest among the 60 areas, whereas in category 2 it is 0.07. In case of other three areas ubiquitous in biomedical sciences, i.e., genetics (*16*), biochemistry (*22*), and information and computer sciences (*29*), the values of the ratios are 0.06, 0.02, and 0.08.

Next we examined the original data of entries (1-II), (2-II), and (2-III) which area equal to 7, 19, and 32. Of seven persons, five selected areas (1) and (2). Thus area (2) is the most contiguous area (1). On the other hand, to area (2), the contiguous areas are pure mathematics (1), information sciences (3), solid-

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Table 1. Areas selected as one's own fields.

	Area	Numbers of areas selected			
		(I) one	(II) two	(III) three	I/(I+II+III), %
1	Pure mathematics	33	7	1	80
2	Applied mathematics; mathematical statistics	4	19	32	7
3	Information science	2	11	27	5
4	Astronomy, upper atomosphere physics	10	4	9	43
5	Nuclear, elementary particle physics	31	6	11	65
6	Solid-state physics	45	56	76	25
7	General physics	6	26	43	8
8	Meteorology, oceanology	4	6	11	19
9	Solid earth sciences	4	3	2	44
10	Geology	3	5	6	21
11	Crystallography; minerology; petrology; economic geology	1	15	20	3
12	Physical, structural chemistry	29	25	61	25
13	Organic chemistry	30	47	46	24
14	Inorganic, analytical chemistry; geochemistry	15	9	39	23
15	Polymer chemistry	8	22	31	13
16	Genetics	1	0	16	6
17	Ecology	1	9	27	2
18	Zoology	8	8	13	28
19	Botany (including plant physiology)	4	20	35	7
20	Microbiology (including bacteriology and virology)	0	6	33	0
21	Biophysics	5	9	25	13
22	Biochemistry	2	31	53	2
23	Anthropology	0	0	1	0
24	Geography	0	2	4	0
25	Human geography	3	1	2	50
26	Materials engineering (including metallology)	33	46	45	27
27	Mechanical engineering	33	36	39	31
28	Control engineering	1	15	28	2
29	Information, computer technology	5	11	47	8
30	Electrical engineering	8	14	44	12
31	Electronics; electrical communication engineering	12	26	61	12
32	Instrumentation	1	15	34	2
33	Navigation and aviation	0	3	5	0
34	Shipbuilding	8	1	2	73
35	Civil engineering	14	26	16	25
36	Urban development, transportation control	0	8	8	0
37	Architecture	10	15	15	25
38	Mining; natural resources	3	5	3	27
39	Industrial chemistry	5	28	35	7
40	Chemical engineering	10	14	16	25
41	Nuclear engineering	3	10	21	9
42	Microbial engineering	2	2	6	20
43	Agronomy	6	13	25	14
44	Agricultural chemistry	9	14	34	16
45	Forestry	6	6	16	21
46	Fishery	2	4	19	8
47	Agricultural engineering	12	11	5	43
48	Animal husbandry; veterinary medicine	7	7	11	28
49	Silk yarn	0	1	2	0
50	Environment; pollution	0	11	33	0
51	Pharmacology (physical; chemical)	2	20	14	6
52	Pharmacology (biological)	3	15	9	11
53	Medicine (basic)	1	8	10	5
54	Medicine (clinical)	0	1	2	0
55	Medicine (social)	0	0	0	
56	Household economy	0	0	3	0
57	Athletics	0	0	0	
58	Philosophy of science and technology	0		5	0
59	Social sciences	4	7	8	21
60	Humanities	1	2	3	17

state physics (6), information and computor technology (29), social science (59), and other physical sciences or engineering. Further by examining the original data of entry (2-III), the combination of areas (2), (3) and (29) is the biggest figure (7 of 32); others are mostly scattered in physics and engineering.

This is concordant with the impressions of foreign visitors that statistics in Japan tends to be concentrated in theory and industrial applications. In my judgement, Japanese statisticians try to be accessible to biological sciences, and sometimes their problems are motivated or inspired by biological problems, but they shy away from the heart of the problems and they are hesitant to claim a commitment to biology.

It would have been interesting if the coverage of the survey included persons in medical schools. Such a survey conducted again including medical scientists, would be another major survey, requiring an investment of millions of yen.

Medical scientists present an unique problem. In Japanese medical schools, there has been a continuous stream of young statisticians who are tacitly, sometimes explicitly, told that they have to look for their future in areas other than medical sciences. The primary responsibilities of senior mathematicians in medical schools are solely giving lectures in mathematics and conducting the entrance examination, and they have full academic freedom to such an extent that they feel free to choose their own research subject, quite often one other than medical sciences, such as operations research, quality control etc. I conjecture that there exists sharp difference between mathematicians and, say, geneticists or chemists in their attitudes toward the primary function of the institutions to which they belong. Probably geneticists or biochemists in medical schools would be more willing to work on the subjects related to medicine than mathematicians and/or statisticians do. The questionnaires prepared did not cover the issue of academic freedom of research and moral responsibility to the institution to which one belongs, which was the basic reason why I did not insist that medical schools be included in the coverage of the survey.

How to Approach Original Papers

In the early part of questionnaires, a question is asked as to how to find original papers useful for one's own research. The respondant is asked to select at most three sources, ranked in order of preference, of seven sources of information:

(1) from reprints of papers sent to him; (2) through personal communications; (3) through scanning recent periodicals; (4) from title listings and indexes of papers; (5) from abstracts of papers; (6) through review articles; (7) others (specify).

We analyzed the numbers of first preferences for the first six sources of informations in each subject area, and we merged sources (1-3) and (4-6) into two groups, the first being source of a private nature and the second being publicly organized service. These two numbers for each area were compared with the respective totals for rest 59 areas of interest in Table 1. For instance, 37, 3 for pure mathematics was compared with $889-37=852$, $322-3=319$, where 889 and 322 are the total figures for the 60 areas. The results are analysed as simple 2×2 tables, and the outcomes are listed in Table 2.

Various kind of explanations have been offered by the members of the project team. Only two points, among others, are indicated here.

First, a great deal of difference exists between pure mathematicians and persons engaged in applied mathematics and mathematical statistics. Secondly pharmacology, (areas 51 and 52), is on the extreme opposite to pure mathematics. Pharmacology is one fields in which individuals consult different scientific information systems, such as Chemical Abstract Service, Biological Abstract Service, Medical Information Service, etc., whereas many mathematicians rarely consult Mathematical Reviews and/or Index of Mathematical Publications. The second point is that pure mathematicians tend to lie are on one extreme of the curve and pharmacologists (and probably medical scientists) on the other.

Mathematical Talent in Cancer Research in Japan

In this section, I will discuss difficulties to be circumvented in utilizing aptitudes for mathematics and/or statistics in biomedical research in general, and cancer research in particular. All are based on my personal experience. (1) Competence in pure mathematics can be acquired and maintained through concentration in isolation, whereas in medicine exposure to variety of biological realities is inevitable. The finding in the previous section is supporting evidences of the great difference between mathematics and medicine. There are not many biomedical research workers who can appreciate this very nature of basic training in mathematics and give advice and guidance for the development of a competent biostatistician.

(2) Young statisticians are frequently disappointed by biomedical sciences. This is natural because ex-

Table 2. Approach to the scientific literature in various specialties.

Area (Table 1)	Source type[a]
(1)	+++
(2)	
(3)	++
(4)	+++
(5)	++
(6)	
(7)	++
(8)	+
(9)	
(10)	++
(11)	
(12)	+
(13)	+
(14)	
(15)	+
(16)	
(17)	
(18)	−
(19)	−−
(20)	−−
(21)	
(22)	−−
(23)	+
(24)	+
(25)	+
(26)	−
(27)	−−
(28)	−
(29)	++
(30)	
(31)	
(32)	−−
(33)	
(34)	−
(35)	−
(36)	−
(37)	−−
(38)	+
(39)	−−
(40)	+
(41)	
(42)	
(43)	−
(44)	−
(45)	
(46)	−−
(47)	
(48)	−
(49)	−
(50)	−−
(51)	−−−
(52)	−−−
(53)	
(54)	−
(55)	
(56)	−
(57)	
(58)	
(59)	−
(60)	−

[a]The symbol + indicates more people in an area rely on private sources (Groups 1-3) than expected from the total with the upper tail probability less than 25%; ++ and +++ are significant at the 5% and 1% level, respectively. The symbol − indicates the same on publicly organized services (source groups 4-6).

perienced leadership is not always available.

(3) In mathematics, emphasis is placed on autonomous or independent creativeness. In medical science, the topic of degree thesis is often concordant with that of supervisors, whereas in case of Rigakuhakushi (Ph.D.) in mathematics it is very necessary to show not only technical competence in mathematics but also that work is beyond the scope of his major professors.

(4) Differences exist not only in academic affairs but also in attitudes and sociological aspects. This may be one of the reasons why mathematicians feel out of place when working with biomedical researchers.

(5) In case of cancer, there is not a firmly established model like that of Mendelian inheritance, which makes mathematicians tend to stay away from cancer research.

(6) In case of the cancer research in Japan, there is no pioneering giant, like Dr. Motoo Kimura in the field of human genetics. In order to promote the cooperation of mathematicians, Japan needs a person like Tautu (*2*), who is a well established mathematician and involved in the mathematical aspects of carcinogenesis theory.

(7) For a mathematician it is very difficult to study basic medical sciences while continuing to maintain activity as a mathematician. It seems that this statement has been periodically and independently repeated by mathematicians and/or statisticians.

(8) It is not easy for a young statistician to become a colleague of medical doctors in biomedical research. This is natural because the expectation is that a young statistician is not generally involved in biomedical research for a long period of his life.

(9) For industrial application of statistics, a government sponsored agency, Japanese Standard Association, supports a variety of activities. It publishes a Glossary of Terms used in Quality Control (*3*) and Statistical Tables (*4*) both of which are naturally oriented to industry. Both are good reference sources for those interested in biostatistics. In case of the biomedicine, I do not know of any organization which is interested in such basic activities.

Concluding Discussion

An effective cancer prevention or treatment is not envisaged in the immediate future, nor is the promotion of mathematical and/or statistical methods in cancer research. We have to start with something very basic.

The Japanese are noted for their competence in mathematics. Quite often, Japanese medical doctors who study in the U.S. take courses in statistics merely for the purpose of acquiring proficiency in English, because the textbooks are almost self explanatory to Japanese. Publishers are interested in publishing papers, which review the recent developments in statistics in medical sciences.

Another article presented at this symposium (5) clarifies why we do not have departments of statistics or biostatistics in our country. It is, indeed, a matter of government regulation and it is far beyond what can be settled in a university campus. In case of biostatistics, consensus among medical doctors plays a vital role.

Biomedical research has been a source of inspiration for statisticians as in any other country in the world; their cooperation based on temporary and personal basis will certainly continue. However, the current status is far below a satisfactory level, probably due to the fact that statisticians do not know sufficient medical science to communicate with medical doctors. In my judgement, the present situation can be improved by providing statisticians with opportunities to study biomedicine.

I quote a passage from an article (6) by D. Vere Jones, a president of the New Zealand Mathematical Society: "The contributions of Japanese science have not been as great as one might expect from acountry of Japan's size, importance and unquestionable technical excellence." I hope the day will come when conferences of this type will be organized by a person whose primary responsibility lies in biostatistics.

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